ASSESSING THE IMPACT OF NEXT GENERATION PRODUCTS ON POPULATION HEALTH: A POPULATION MODELLING APPROACH

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CHALLENGE: PREDICTING THE IMPACT OF AN NGP

IMPERIAL BRANDS SCIENCE

- What can we predict about introducing a new low-risk product (“NGP”: Next Generation Product) smokers, users of incumbent vapor products (“vapers”), and others (“nonusers”)?
- Typical population models (Markov models) can answer the question “if we *assume* the uptake by {people with a particular behavior} is {percentage each year}, what is the resulting arithmetic for 20 years?”
- An alternative approach, agent-based modeling, can tell us more.

AGENT-BASED MODELING

- Instead of making high-level assumptions about types of people (e.g., “2% of smokers will switch to this product each year”),
- it is possible to model individual preferences, propensities, and “decision” making processes that:
  (a) replicate historical observations
  (b) then make prediction about the future that are not effectively just the input assumptions

Footnotes:

Software used: NetLogo 6.2.0

Person-first language (e.g., “people who smoke”) should really be used when talking about real people. However, since this is all about simulated agents, it is not dehumanizing to use characteristic-based language like “smokers”.

METHODS (1/5) - CHARACTERISTICS OF AGENTS (SIMULATED PEOPLE)

- propensities to smoke, vape (incumbent vaping products), use NGP
- behavior status (smoker, vaper, NGPer, none)
- age
- cohort identity based on approximate age at baseline of 20, 30,...,60, with a youngest cohort (10 at baseline) being added when they come of age
- social network of other agents who influence propensities

METHODS (2/5) - TIMELINE

- Model runs from 2005 to 2050 (with the recognition that any predictions toward the end of that period are very tenuous).
- Vaping is becomes an option in 2009.
- NGP is introduced in 2022.

METHODS (3/5) - PRODUCT USE “DECISIONS”, OVERVIEW

- If agent’s (random) baseline propensity to smoke exceeds a global threshold, they start as a smoker.
- Smokers are inclined to switch (with a chance of switching each period) to vaping or to the NGP if their propensity for the other is higher than for smoking.
- Vapers and NGPers can similarly switch between the products.
- Nonusers can adopt the NGP if their propensity exceeds a threshold.

METHODS (4/5) - PRODUCT USE DECISIONS, SOCIAL CONTAGION

- An agent's propensities change over time in response to "seeing" a product being used.
- Every agent has a network of "peer influencers" whose behavior influences their propensities.
- Each period, having peer influencers who vapes or NGP increases an agent's propensity for that product.

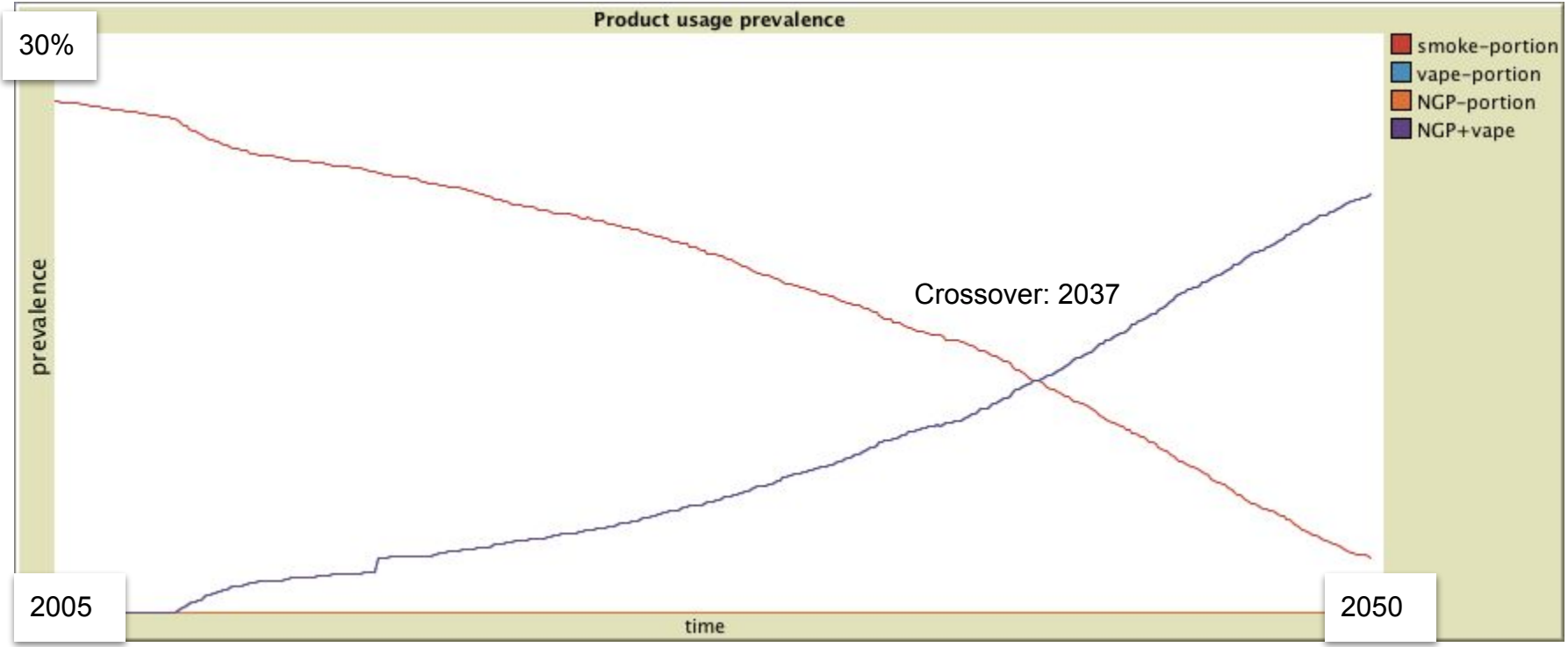
METHODS (5/5) - HISTORICAL “TUNING”

- Agent-based models allow us to “tune” the structure and parameters to replicate historical observations (U.S. population, 2005-2021) and then let those play out in the future.
- The aforementioned structure was chosen as seemingly realistic and also replicating historical patterns.
- Further adjustment to get each cohort’s behavior to match their historical numbers: scalar additions to their baseline smoking and vaping propensities.
- It is reassuring about the usefulness of the model that a consistent realistic behavior structure and a small number of cohort-specific parameter adjustments are sufficient to replicate historical data.

BASELINE SCENARIO: THE FUTURE WITHOUT AN NGP

- This scenario should be considered more as part of the methods than the results *per se*.
- It *is* the prediction of this seemingly valid model.
- But a lot changes over time, so the most robust predictions of any model are how alternative scenarios differ from a baseline.

BASELINE SCENARIO: THE FUTURE WITHOUT AN NGP



BASELINE SCENARIO: THE FUTURE WITHOUT AN NGP

- Key output measure: Alternative product use (vaping only in this case) surpasses smoking in popularity in 2037 on average (within +/- 1 year in approximately all runs).
  - Note that because of the random processes, there is natural variability across model runs. However this and most every key output is almost always about the same.
  - The graphs presented herein are each a single run of the model, for the entire population.

- To put the comparison of that to other scenarios in practical perspective, for the population of U.S. smokers in 2005, a shift of one year earlier to this crossover time represent about 7.3 million person-years of smoking
  - based on typical estimates of health effects, this represents roughly 1 million life-years

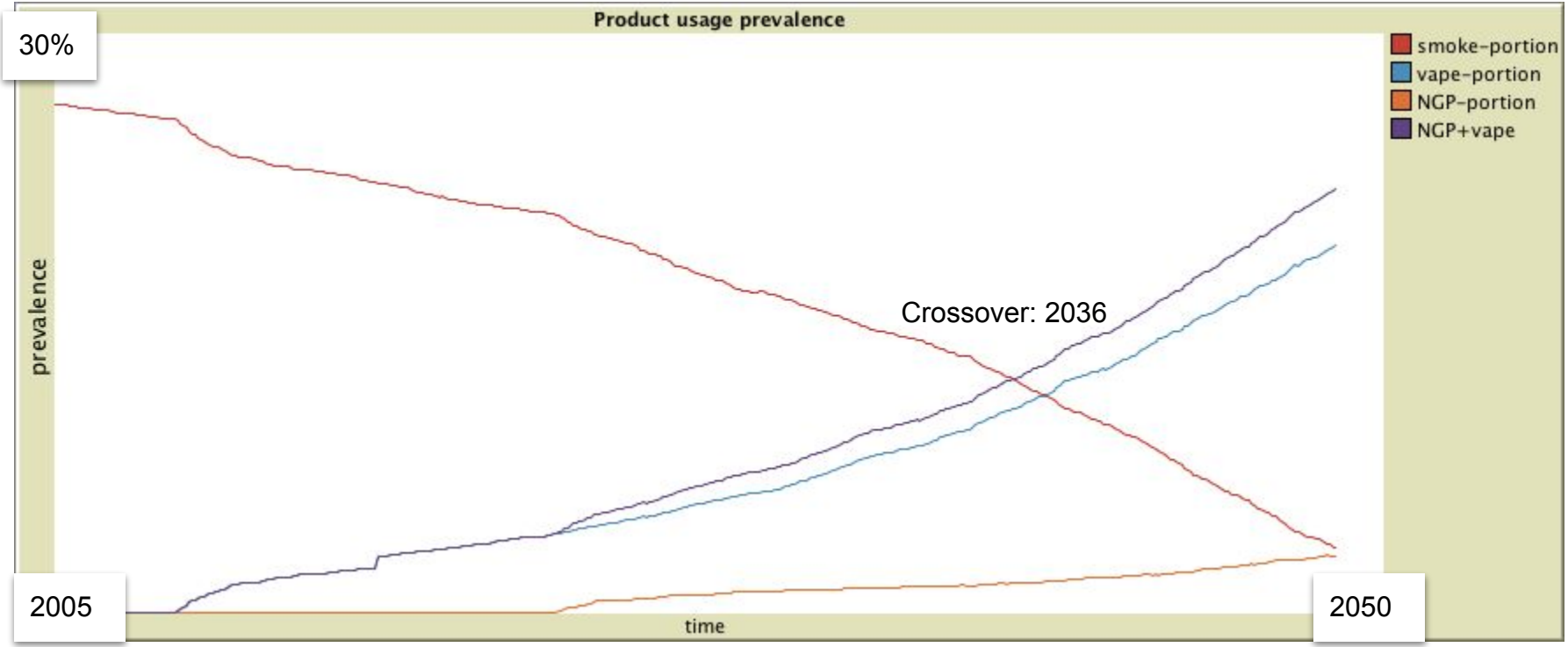
ADDING THE NGP. WHO DOES IT APPEAL TO?

- The most useful feature of the agent-based approach is that individuals have preferences, not just behaviors.
- How are propensities to adopt the NGP distributed (i.e., *who* likes it more) matter.
- A Markov model assumes anyone with a particular behavior is equally inclined to switch. The present model can tell us more.

SCENARIO 1: NGP WITH UNCORRELATED PREFERENCES

- Consider first the unrealistic case where agent propensities for the NGP are totally random with respect to their propensities for smoking and vaping.
- Recall:
  - Smokers or vapers probabilistically switch (starting in 2022) if that propensity exceeds their propensity for their current behavior.
  - Nonusers adopt the NGP if social contagion raises their propensity high enough.

SCENARIO 1: NGP WITH UNCORRELATED PREFERENCES



SCENARIO 1: NGP WITH UNCORRELATED PREFERENCES

- These results should be considered a calibration and basis for comparison, not a meaningful prediction.
- ~1% of the population are NGP consumers after 2 years.
- Alternative products (vaping + NGP) surpass smoking one year sooner than vaping alone. By 2050, over 4% of the population are former smokers who switched to the NGP.
- Almost no NGP adopters were vapers. Almost all switch from smoking at first.

SCENARIO 1: NGP WITH UNCORRELATED PREFERENCES

- That “at first” produces the first interesting result:
- With a contagion effect as strong for nonusers as for smokers, nonusers become majority of adopters 20 years out.
- This seems unrealistic (based on observed uptake of existing alternative products across populations) so the model was recalibrated with to reduce contagion effect to nonusers by 2/3, resulting in
  - very little nonuser uptake (by construction),
  - so former nonuser-NGPers do not contribute social contagion,
  - and as a result, far fewer smokers switch: only about 2% of the population are former-smoker-NGPers by the end of the run, rather than 4%.

SCENARIO 1: NGP WITH UNCORRELATED PREFERENCES

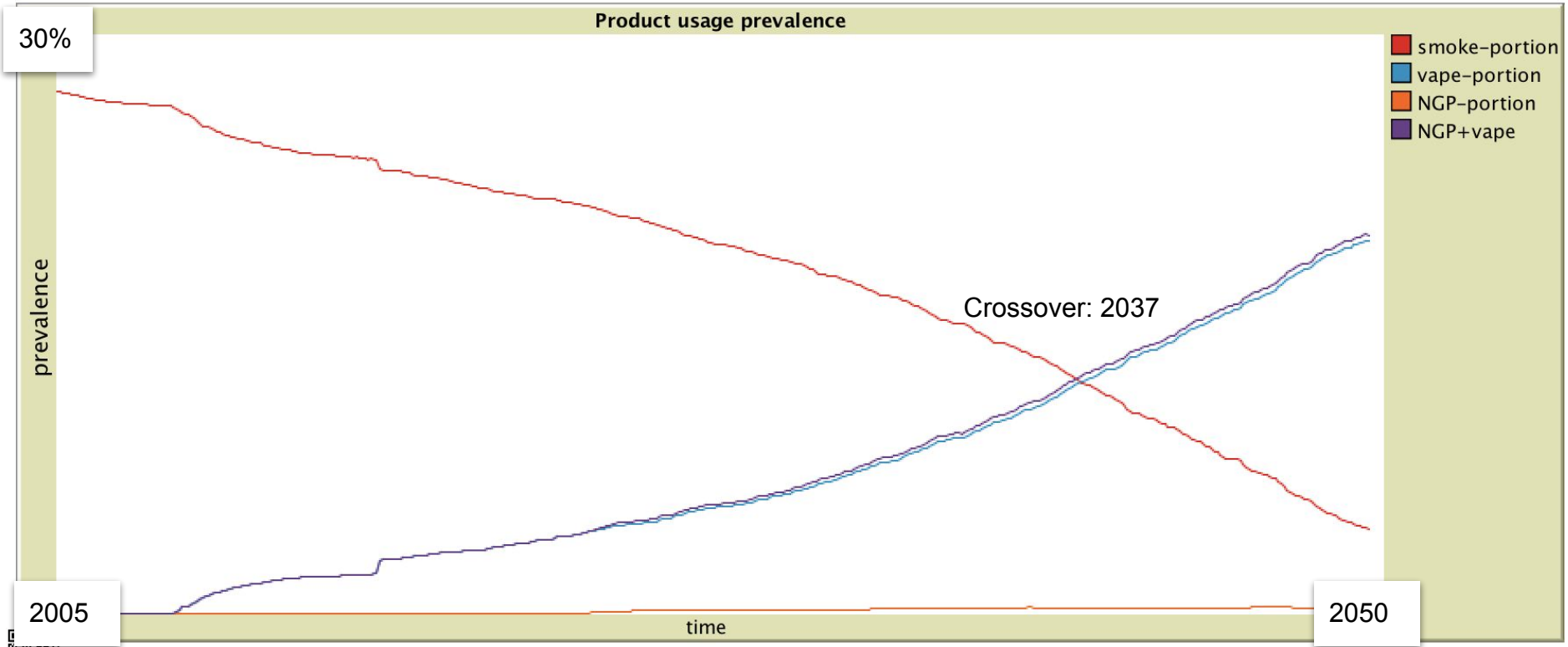
- We are not making any normative or ethical judgment here.

- But this material implication of the model outputs does seem legitimate: The fewer nonusers who adopt a product, the fewer smokers will also switch to it.

SCENARIO 2: NGP PROPENSITY IS CORRELATED WITH VAPING

- In this scenario, the NGP appeals more to those who have a higher propensity for vaping (e.g., it is an improved vapor product)
  - specifically, NGP propensity is an average of vaping propensity and a random number
- Important observations:
  - The average NGP propensity across the population is the same in this scenario (and the scenario that follows) as in the previous one. What changes is *who* it appeals to
  - The correlation is not all that tight, but the effects turn out to be dramatic

SCENARIO 2: NGP PROPENSITY IS CORRELATED WITH VAPING



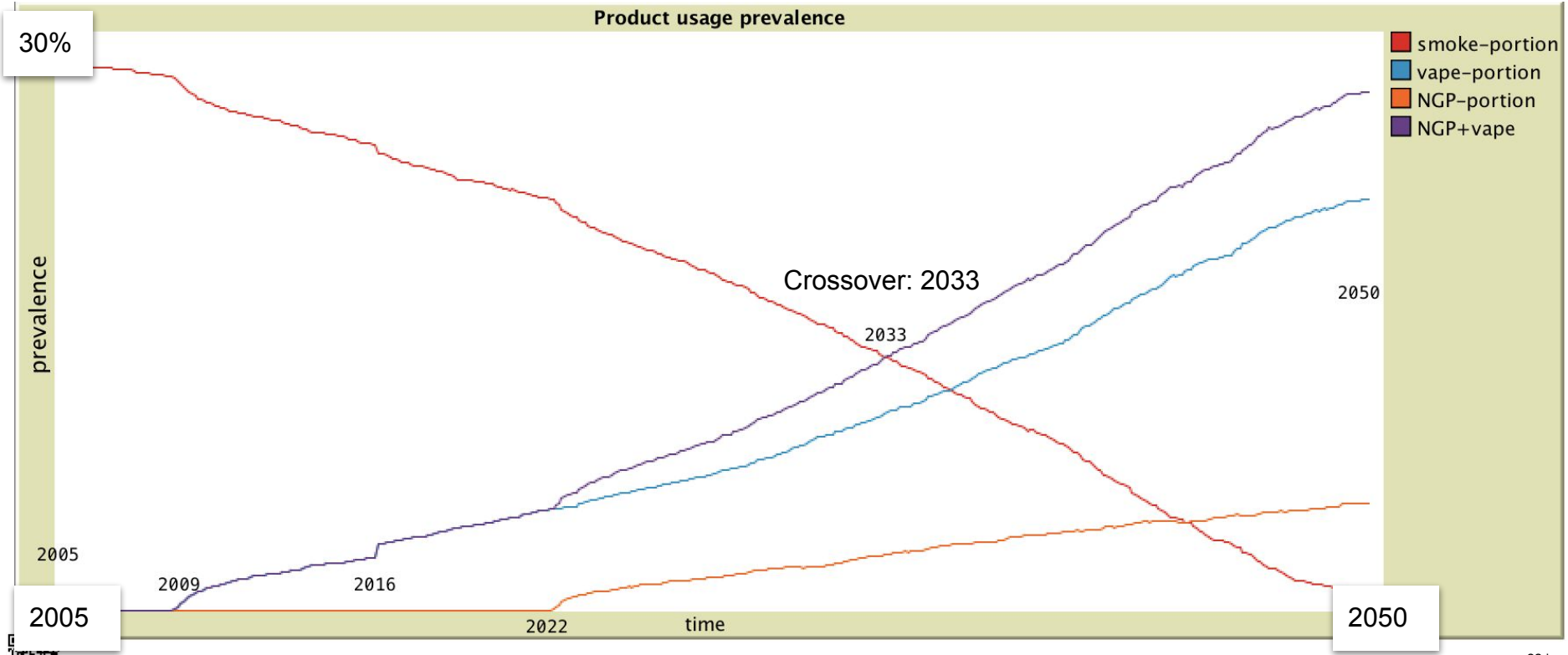
SCENARIO 2: NGP PROPENSITY IS CORRELATED WITH VAPING

- With high probability, the NGP fails in the market (as in the graph presented). It has almost no effect on smoking prevalence.
- However, for a small portion of runs, the “butterfly effect” from random initial differences and the contagion effect result in the new product becoming popular (a realistic picture of a new entrant in an established market).
- Still, in those cases the switchers are mostly incumbent vapers or smokers who would have switched to vaping anyway, so the reduction in on smoking remains small.

SCENARIO 3: NGP PROPENSITY IS CORRELATED WITH SMOKING

- In this scenario, the NGP appeals more to those who have a higher propensity for smoking (think: heated tobacco products in Japan)
- The parameterization is like that for the previous scenario: an average of smoking propensity and a random number.

SCENARIO 3: NGP PROPENSITY IS CORRELATED WITH SMOKING



SCENARIO 3: NGP PROPENSITY IS CORRELATED WITH SMOKING

- Alternative products (vaping + NGP) overtake smoking in 2033 or 2034, about 3.5 years earlier than in baseline scenario.
- Almost 1/4 of everyone who smoked switches to the NGP.
- Very few vapers switch. Very few nonusers adopt the NGP.
- Smoking is driven to nearly zero by 2050 (with about 7% of the population using the NGP and 19% of the population vaping).

- The contrast across the three scenarios is entirely the result of *who* the NGP appeals to. The average propensity is the same.

SUMMARY OBSERVATIONS

- This model suggests that realistic variations in *who* likes a new product make more of a difference (in terms of smoking cessation, and also market success) than *how much* the product is liked on average.
- The limited association presented for NGP propensity and smoking propensity has a similar effect (compared to the uncorrelated baseline) to increasing everyone's NGP propensity by over 10%.
- This is a result of modeling realistic preferences and behavior, not mere input assumptions about the percentage of smokers who switch each period.

SUMMARY OBSERVATIONS

IMPERIAL BRANDS SCIENCE

- It goes without saying that a NGP that smokers like better will attract more of them to switch.
- But it is often overlooked in the modeling literature that -- in a maturing low-risk alternatives market -- a NGP that might have changed everything in 2005 might have little effect in 2022 if it does not appeal to the *right* people.
- Any new product will produce welfare benefits (some people will like it better than available options, all things considered) and reduce smoking. This will improve health outcomes (assuming the new product is sufficiently low-risk).
- However, the magnitude can vary a lot based on factors that are seldom incorporated into the models.