# VACCINE PRODUCTION IN DEVELOPING COUNTRIES: AN ECONOMIC EVALUATION

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# Preview

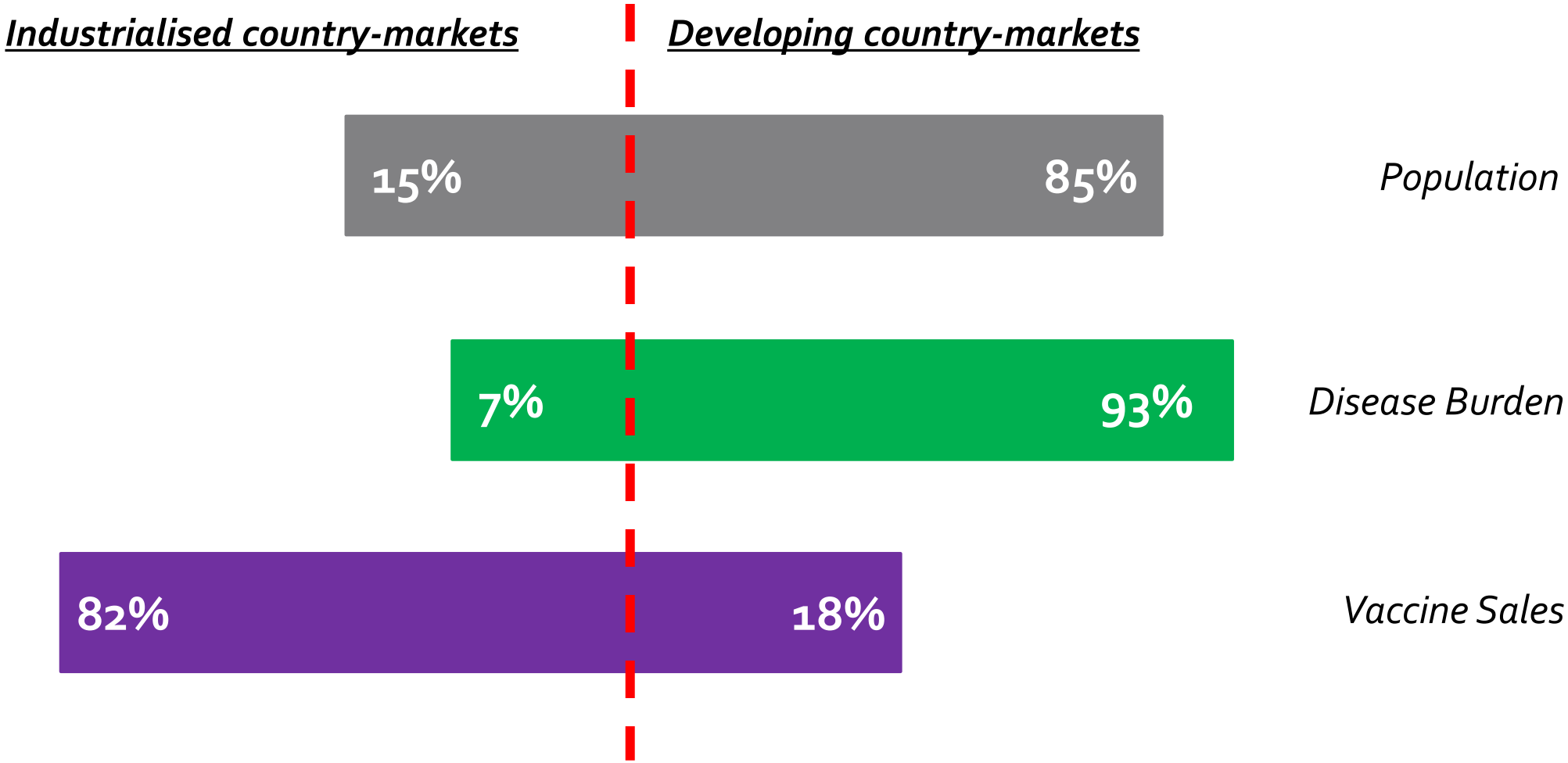
- Context: Local vaccine production in developing countries
- Framework: Economic evaluation of establishing new vaccine facilities in developing countries
- Methodology:

1. Cost analysis using questionnaire on existing vaccine manufacturers in developing countries
2. Econometric analysis on viability factors influencing market shares and revenue size of developing country manufacturers

- Results and Conclusions:

1. Cost structure and cost drivers
2. Viability factors influencing market shares and revenue sizes

# Gap Between Vaccine Markets




*Source*: Kaddar, M. (2013). *Global Vaccine Market Features and Trends*. Paper presented at the Workshop on Business Modelling for Sustainable Influenza Vaccine Manufacturing, Washington DC.

# Characteristic of the Vaccine Industry

- High fixed costs
- Small market (2 – 3% of pharmaceuticals market)
- High price – cost margin
- Scrutiny on price and quality
- Different market for different vaccine antigens, no overlap
  - High market concentration
- Investment decisions based on economic considerations

# Study on costs of establishing new vaccine facilities in emerging markets

*Background*

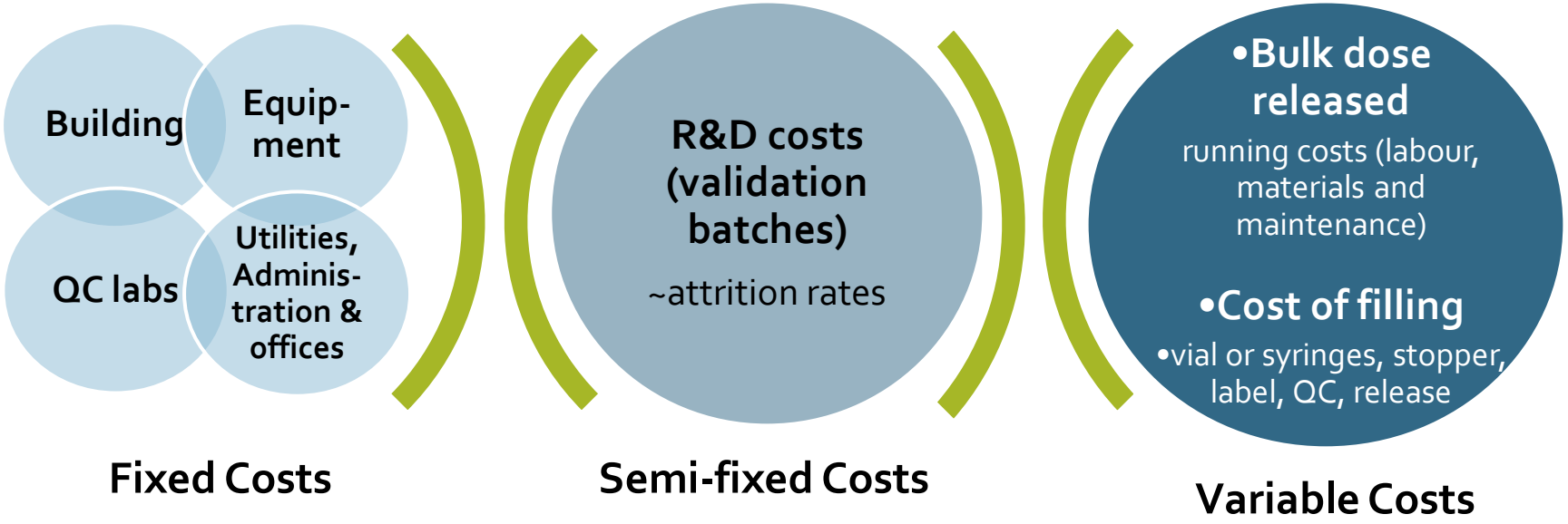
- Existing literature are limited
  - Mahoney (1990), Mahoney et al (2012), Mercer study (2002), Mercer study (2006)
- Expressed interest by countries to WHO wishing to establish local vaccine production
- Need for analysis of whether local production is in fact suitable for each country that expresses these interests
- Sensitive data

*Methodology*

- Questionnaire (8 respondents, 12 observations)
- Self reporting
- Broad estimation
- Hypothetical scenario of scale and scope

  (production capacity & number of vaccines)

# Questions asked: Production costs



# Fixed costs: 3 scenarios

| Scenario | Annual Doses | Vaccines Produced |
|---|---|---|
| Scenario A | 20 million | 1 vaccine |
| Scenario B | 20 million | 5 vaccines |
| Scenario C | 100 million | 5 vaccines |

*Effect of greater production scope*

*Effect of greater production scale*

# Analysis

- **Observations segregated by:**
  - Vaccine technology
    - Bacterial
    - Viral
    - Combination
    - Recombinant
    - Conjugate
    - Novel
  - Vaccine formulation
    - Multi-dose vials (10 dose)
    - Single-dose vials
    - Pre-filled syringes
    - Lyophilized

- **Assumptions:**
  - Attrition rates
  - Equipment life-years
  - $C_a = (V - R)_a$

$C_a$ : annualized capital cost of equipment

$V$ : acquisition cost of equipment

$R$ : estimated residual value

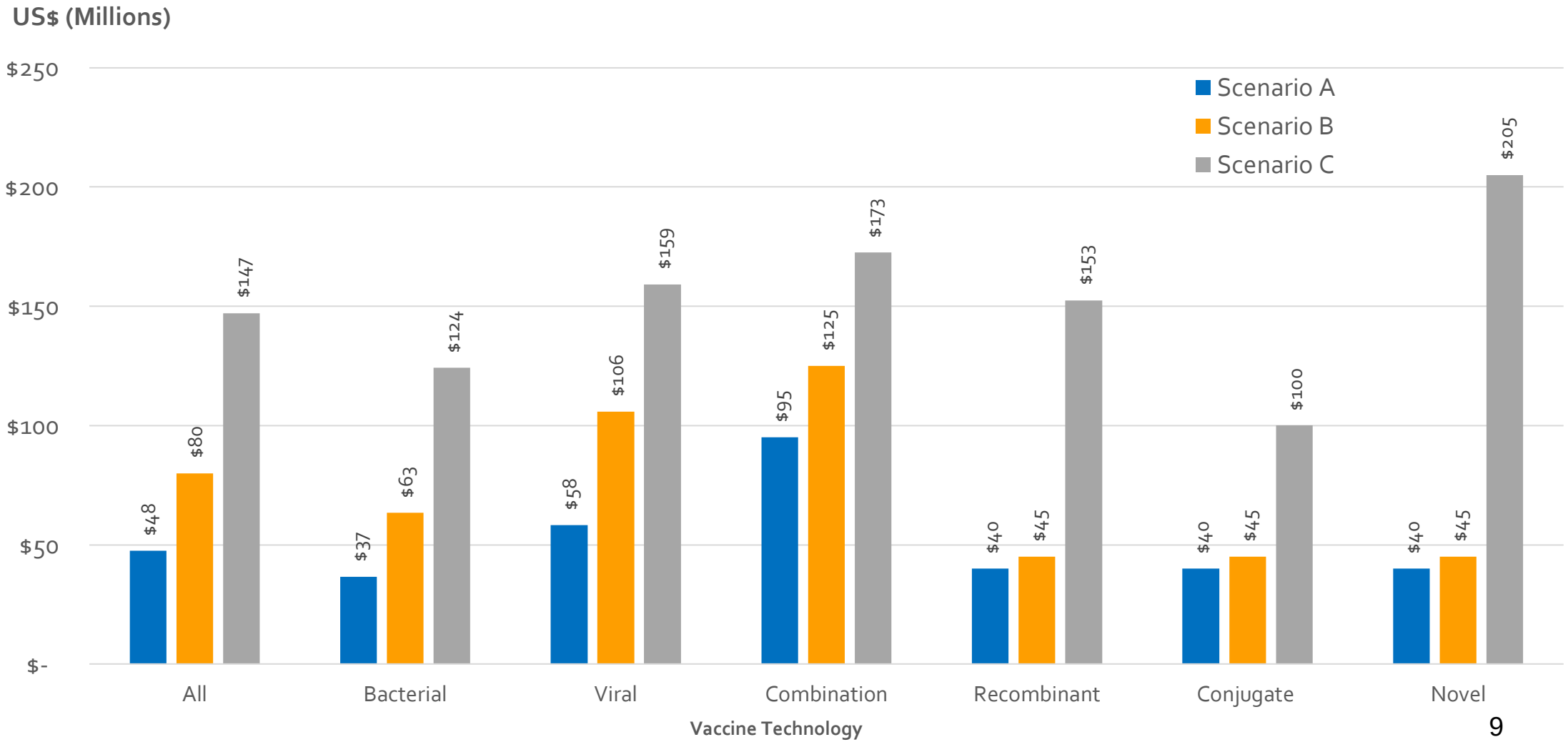
$a$ : annualization factor $= \frac{\boldsymbol{r(1+r)^n}}{\boldsymbol{(1+r)^n-1}}$

| | Building | Equipment | Validation |
|---|---|---|---|
| interest rate (r ) | 10% | 5% | 5% |
| years (n) | 25 | 10 | 10 |

Assumptions adopted from: Mercer Management Consulting (2002); Mercer Management Consulting (2006), Mahoney (1990) and Mahoney et al. (2012) and Levin (1983)

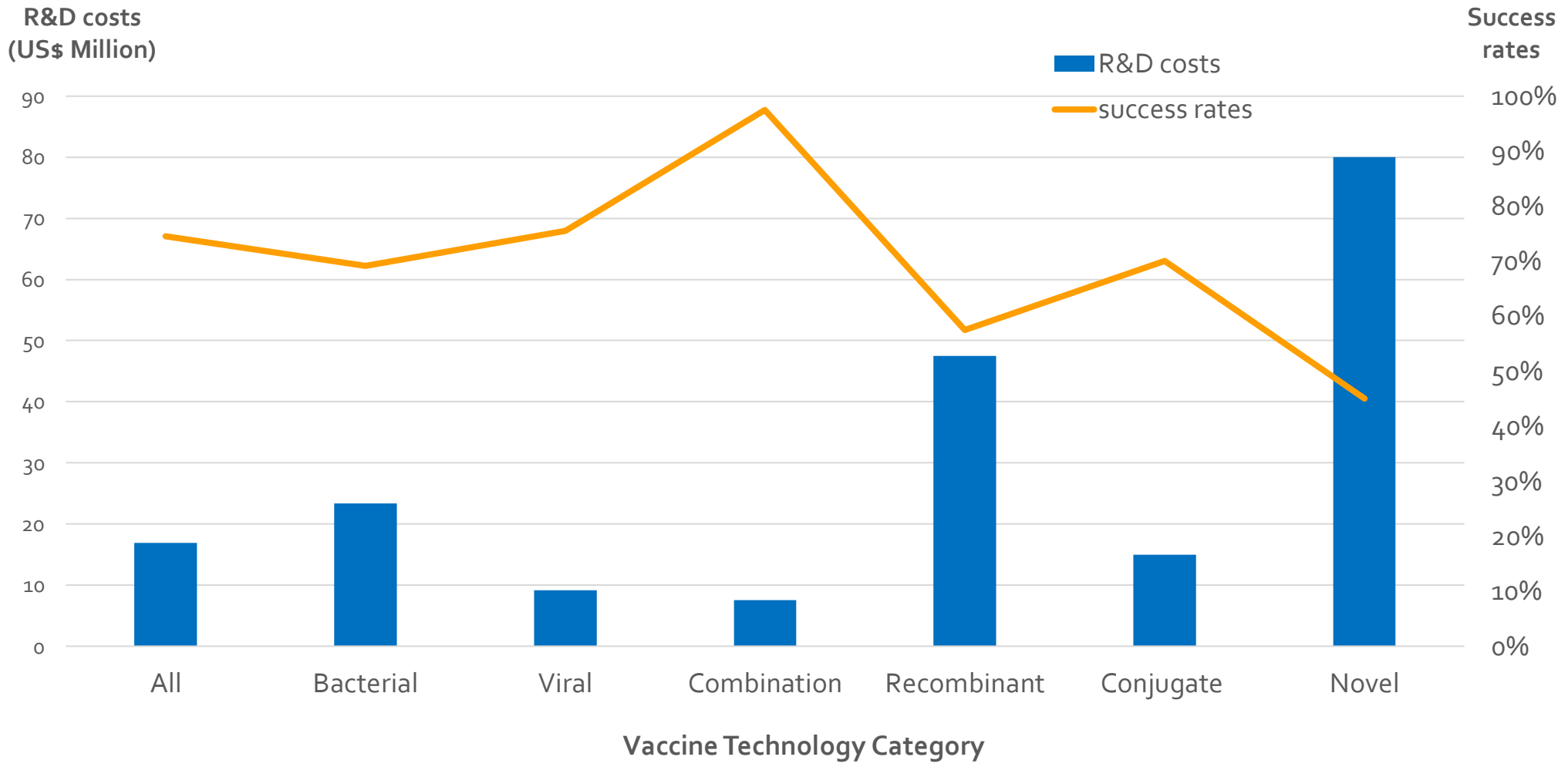
*Findings*

# Step fixed-costs: importance of demand forecasting



*Findings*

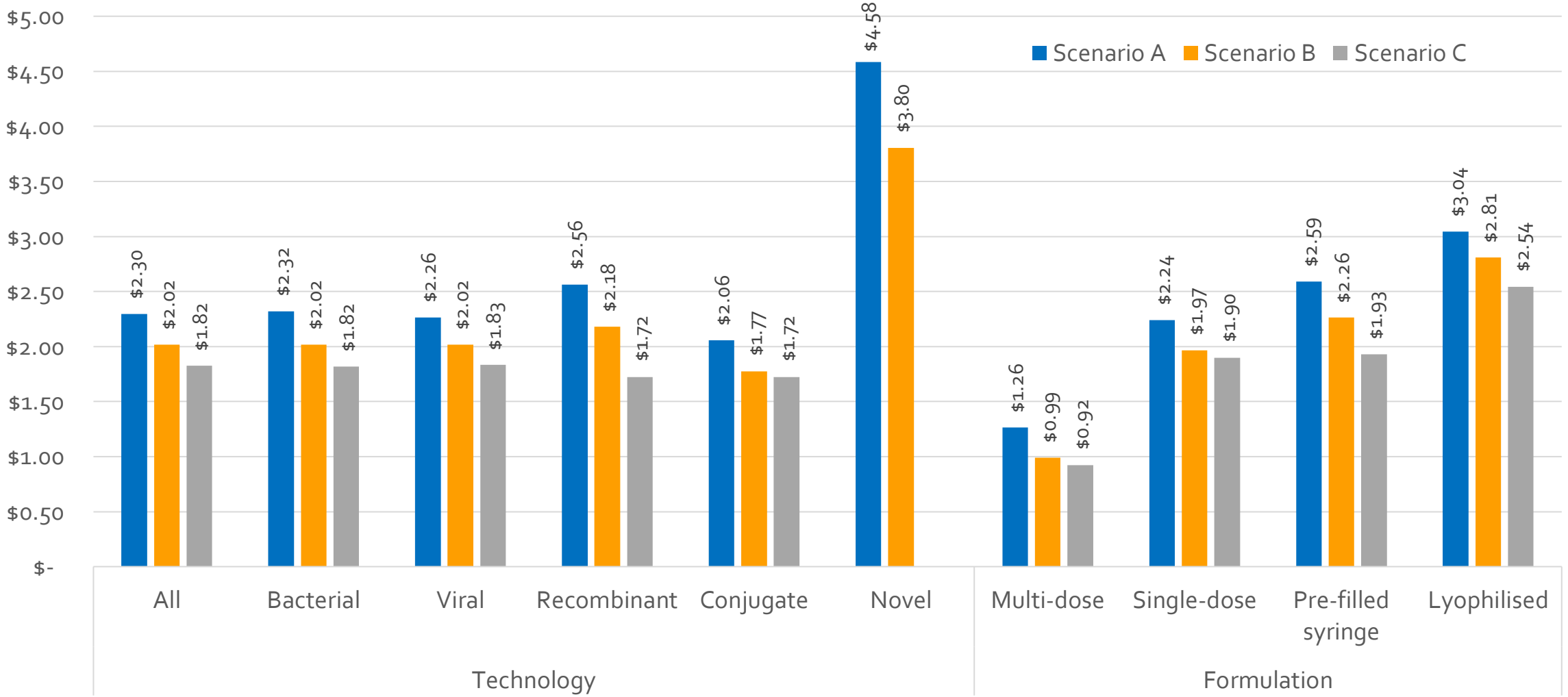
# R&D costs and failure rates significantly lower than originating vaccines



*Findings*

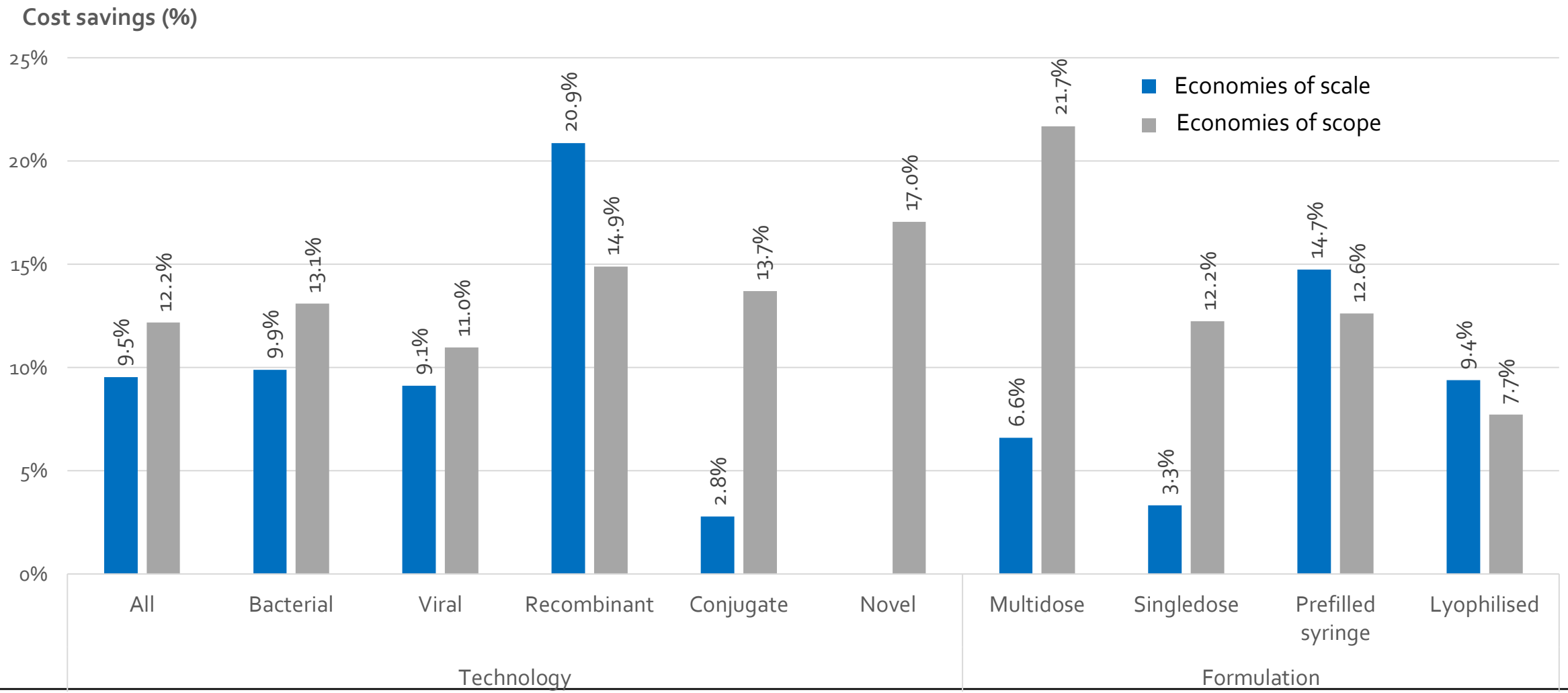
# Average vaccine cost-per-dose*: $2.05 (range: $0.92 - $4.40)

*based on 3 specific production scenarios



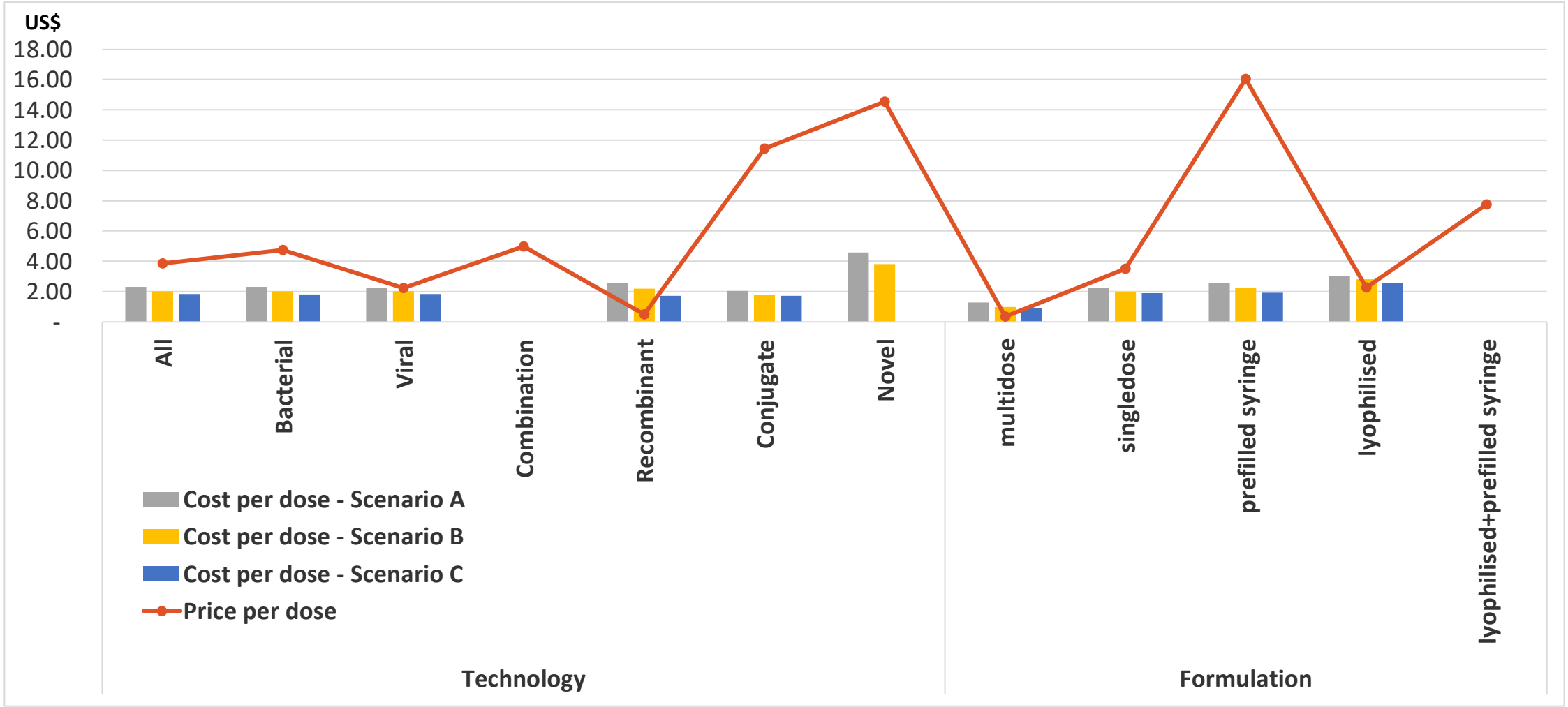
*Findings*

# Existence of economies of scale & economies of scope in developing country vaccine production



*Findings*

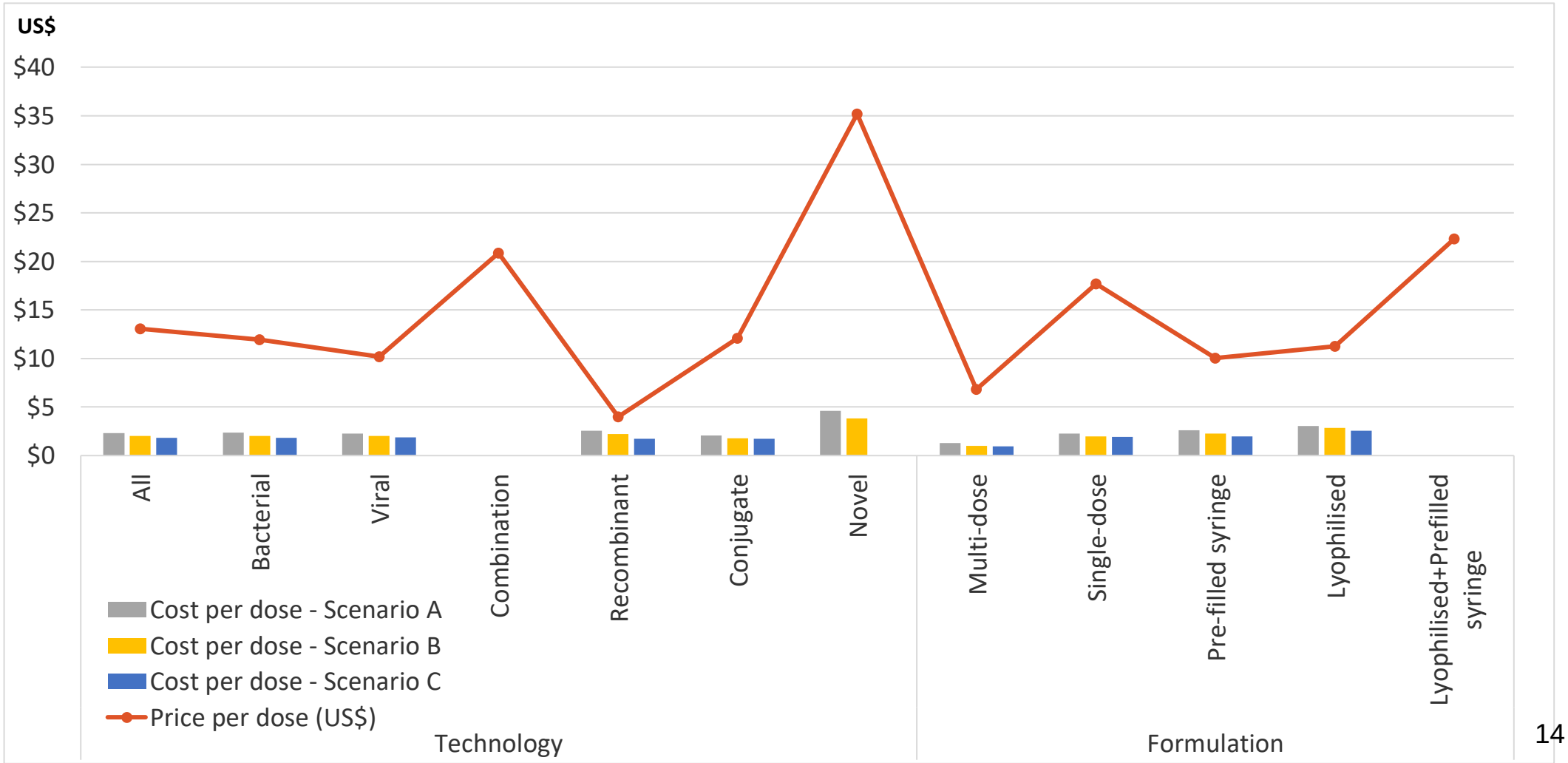
# Producer surplus in developing country markets*: bacterial and conjugate | pre-filled syringes




*based on 3 hypothetical scenarios & existing market price

*Results*

# Producer surplus in industrialized country markets*: need to match epidemiological demand & regulatory requirements




*based on 3 hypothetical scenarios & existing market price

# Cost drivers of vaccine production in developing countries

- High fixed costs offset by:
  - Large volumes and multi-vaccine facilities
  - Technology types and formulation presentations
- Mainly driven by fixed costs, but at production scales over 20 million doses, becomes driven by its variable costs (an advance on the current literature)
- Developing country vaccine manufacturers face mostly non-premium markets, yet compensated by:
  - large size of the population
  - high need for vaccines due to disease burden profiles
  - low domestic competition
- Challenges to sustain viability when exporting vaccines or producing new technology vaccines

# Econometrics analysis: Multilevel regression (3-level HLM) on panel data (2012 – 2014)

***Viable Production***

1. ***Market share, global market***
2. ***Revenue size, domestic market***
3. ***Market share, export market***

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***Viability characteristics***

- **Economies of scale**
- **GMP/consistency of production**
- **Access to new technologies**
- **Historical performance to meet demand and scale up production**
- **Credibility of quality**
- **Management structure**
- **Legal status, adequate autonomy**
- **National income per capita**
- **Market expansion strategy**

# Data source (2012 – 2014)

- World Health Organisation:
  - 'Source of Vaccines' database as reported in WHO/UNICEF's Joint Reporting Form (annual)
  - Administrative coverage database
  - Vaccine schedule database
  - Vaccine product, price and procurement ($V_3P$) database
- World Bank:
  - World Development Indicators database
- Vaccine Information Management System (VIMS) database, John Hopkins Bloomberg School of Public Health
- Vaccine manufacturers' and relevant governments' websites.

# Descriptive Analysis

- Data size: approx. 4.55 billion doses, $ 5.74 billion
- 311 observations based on 40 vaccines types produced by 34 manufacturers in 16 countries
- 118 combinations over 3 years (2012 – 2014)
- Inclusion: vaccine doses procured from developing country manufacturers
- Exclusion: vaccine procurement reported as multiple sources

*Findings*

# Multilevel regression analysis: Vaccine viability factors on market shares

| Independent Variable | Market share, global market | | Revenue size, domestic market | | Market share, export market | |
|---|---|---|---|---|---|---|
| | coefficient | p-value | coefficient | p-value | coefficient | p-value |
| Constant | -13.51 | | -12.32 | | -7.83 | |
| Surviving Infants (log) | **-1.00** | **0.021*** | **0.95** | **0.000**** | -0.38 | 0.654 |
| Number of vaccines products | **0.10** | **0.026*** | 0.18 | 0.531 | **0.10** | **0.022*** |
| Consistent production supply | **0.90** | **0.001**** | **1.61** | **0.000**** | **1.48** | **0.001**** |
| Vaccine technology | **0.79** | **0.000**** | **0.74** | **0.000**** | 0.34 | 0.083 |
| Sufficient supply against demand | **0.70** | **0.010*** | 0.33 | 0.335 | **0.80** | **0.028*** |
| NRA | 0.83 | 0.125 | 0.18 | 0.761 | **3.12** | **0.003*** |
| Vaccine PQ status | **0.98** | **0.000**** | -0.21 | 0.561 | **1.15** | **0.002*** |
| Ownership status | **1.01** | **0.011*** | **1.26** | **0.004*** | **1.45** | **0.041*** |
| Number of MOH, last 5 years | 0.06 | 0.588 | 0.06 | 0.411 | -0.07 | 0.823 |
| National income per capita | **0.48** | **0.046*** | **1.17** | **0.000**** | 0.53 | 0.272 |
| Proportion of export sales | **-1.00** | **0.000**** | | | | |

*: p-value < 0.05; **: p-value <0.001; bold number: significant

Source: Analysis based on Munira, S.L (2017) "Viability vaccine of local vaccine production..", ANU

# Once up and running – developing country vaccine production viability factors

**Market shares:**

| Domestic markets | Export markets |
|---|---|
| • Production scale<br>• Sustainable and reliable production<br>• Autonomous management structure<br>• **National income level**<br>• **Vaccine technology type** | • Production scale and scope<br>• Sustainable and reliable production<br>• Autonomous management structure<br>• **Fully functioning NRA**<br>• **Prequalified vaccines** |

# Key messages

- Production scale and scope are essential in achieving and sustaining viability
- Step costs in vaccine production – production set up and planning is critical
- Sustainable and reliable production essential in maintaining market share
- Establishing strong domestic presence important prior to expanding into export markets
- Formulation types are cost drivers yet not a determining factor on price

# Acknowledgements


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***Thank you***

# Econometrics analysis: Mixed-model regression on panel data (2005 – 2015)

***Vaccine Prices***

***Developing Country Manufacturers***

- ***Traditional vaccines***
- ***Modern vaccines***

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***Procurement factors***

- ***Volume***
- ***Procurement Mechanism***
- ***Contract***
- ***Formulation***
- ***Formulation size***
- ***Vaccine technology***
- ***Income level (Procurer)***
- ***Income level (Manufacturer)***
- ***Competition***

# Data source (2005 – 2015)

- World Health Organisation:
  - Vaccine product, price and procurement (V3P) database
  - Prequalified (PQ) vaccines' list
- World Bank: country classification

| | Developing country manufacturers |
|---|---|
| **Doses** | 0.51 billion |
| **Revenue** | $ 0.4 billion |
| **Observations** | 392 |
| **Vaccine types** | 25 |
| **Manufacturers** | 20 |
| **Producing countries** | 8 |
| **Procuring countries** | 43 |

*Note: based on V3P participating countries reporting to WHO*

# Multilevel regression analysis : Procurement factors on vaccine prices – Developing country manufacturers

| Independent Variable | Price/dose (log) | |
|---|---|---|
| | coefficient | p-value |
| **Constant** | **-0.70** | |
| **Volume (log)** | **-0.05** | **0.007*** |
| **UN Procurement** | **-0.84** | **0.000**** |
| **Contract** | -0.10 | 0.384 |
| **Formulation type** | -0.01 | 0.912 |
| **Formulation size** | **-0.06** | **0.000**** |
| **Vaccine Technology** | **0.91** | **0.003*** |
| **Income Level (Procurer)** | **0.17** | **0.025*** |
| **Income Level (Producer)** | **0.49** | **0.000**** |
| **No. of substitutes (PQ)** | 0.00 | 0.857 |

*: p-value < 0.05; **: p-value <0.001; bold number: significant

Source: Analysis based on Munira, S.L (2017) "Viability vaccine of local vaccine production..", ANU

# Procurement factors on developing country vaccines pricing behaviour

| All vaccines | Traditional vaccines | Modern vaccines |
|---|---|---|
| • Volume<br>• **UN Procurement**<br>• **Formulation size**<br>• Income level (Procuring & Producing country) | • **UN procurement,**<br>• **Formulation size,**<br>• Income level (Producer) | • Volume<br>• **UN Procurement**<br>• **Formulation size** |

- **Vaccine pricing behavior compared to other manufacturers:**
  - Formulation type not a determining factor on price
  - Traditional vaccines are saturated, hence volume does not influence prices