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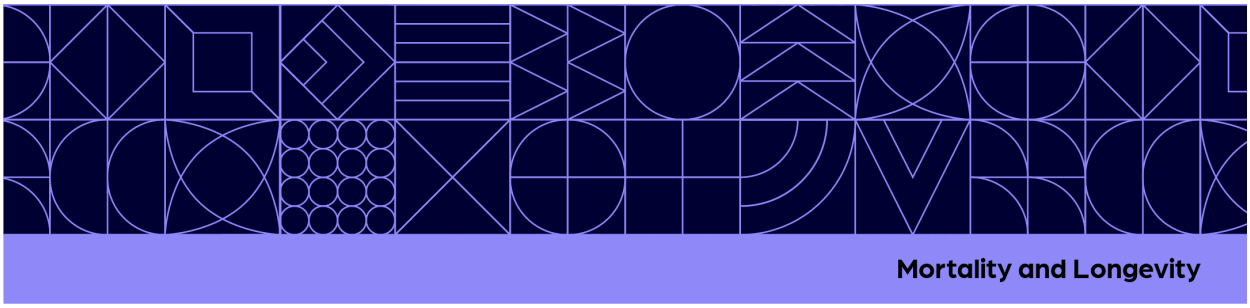

建模评估野火相关空气污染对死亡率的影响

执行摘要

本报告旨在探讨野火及更广泛的空气污染对死亡率的影响，重点介绍与寿险相关的建模方法。虽然野火会造成直接死亡（例如由烧伤和烟雾吸入所导致的死亡），但其对死亡率更显著的影响来自于空气污染的增加。野火烟雾提高了有害污染物的浓度，尤其是细颗粒物（PM2.5 和 PM10）。这些污染物会引发慢性疾病，并导致长期超额死亡率——这种超额死亡率往往不直接与野火事件挂钩。如何准确量化污染与死亡率之间的这种间接、滞后关系，是主要的建模挑战。本报告通过三种建模方法应对这一挑战，每种方法适用于不同的精算应用场景和时间范围：

1. 随机死亡率框架：该方法是在 Lee-Carter 模型的基础上，通过纳入气候变量来估计短期至中期的影响。当污染指标与死亡率之间存在较强的实证关系时，该方法最为有效，并且可与保险公司现有的随机框架兼容。
2. 患病率情景法：根据可归因于污染的疾病患病率的预期增加来预测死亡率。这种直观的方法与发病率建模实践相一致，但其可靠性依赖于疾病患病率数据以及全球疾病负担死亡率估计值，后者来源于统计建模而非实际人数统计。

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3. 世界卫生组织 AirQ+ 方法：该流行病学模型使用浓度-反应函数来估计可归因于 PM2.5 和臭氧等污染物的死亡人数。虽然该方法适合情景测试，但需要谨慎校准，并且由于浓度-反应函数本身所包含的假设，可能无法完全反映当地情况。

在上述所有方法中，均识别出以下几个局限性：

- 数据颗粒度不足：准确的建模需要具有地理和时间维度的详细死亡率数据。
- 历史数据缺口：长期污染物暴露建模受到历史监测量数据稀疏的限制。由于监测站数量不足或数据收集频率不够（尤其是在较早年份），难以获得可靠空气污染数据的全面历史记录。
- 人口动态变化：基于历史数据的校准可能无法反映未来脆弱性或暴露程度的变化。
- 空间平均效应：州一级的数据可能掩盖了局部的污染热点和地形效应。
- 交互效应缺失：现有模型无法捕捉污染与其他气候压力因素（如热浪或行为调整）的综合影响。

尽管存在这些挑战，这些模型仍然为精算师评估环境风险提供了有价值的工具。它们可以为压力测试、定价调整以及量化与气候相关的死亡率冲击提供信息。例如，针对特定地区的污染风险因子可以支持死亡率分区的制定，或针对野火多发地区调整定价。

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